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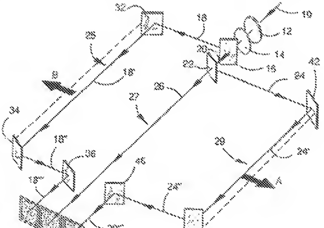
(54) Title: OPTICAL SYSTEM AND METHOD FOR PRODUCING FOCUSED AND DEFOCUSED IMAGES



(57) Abstract: An optical system for concurrently producing images of an object for use in phase imaging of the object is disclosed. The system includes beam splitters (16, 20) for splitting a beam of light (10) into a plurality of different paths (25, 27, 29). Mirrors (32, 34, 42, 44) define first and second paths which have different lengths with respect to one another and light transmitted through the beam splitter (22) defines a third path (27) which has a different length to the paths (25, 29). Charge coupled device (30) is provided for imaging the light travelling along the paths (25, 27, 29) concurrently onto the charge coupled device for producing three images concurrently on the charge coupled device, with one of the images being an in focus image, one of the images being positively defocused, and the other image being negatively defocused.

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OPTICAL SYSTEM AND METHOD FOR PRODUCING FOCUSED AND DEFOCUSED IMAGES

Field of the Invention

This invention relates to an optical system and method for concurrently producing focused and defocused images of an object. The invention has particular application to the formation of images required to produce a phase image of the object.

Background of the Invention

It is known that a phase image of an object can be generated by quantitative determination of the phase of the radiation wave field emanating from the object. In International Patent Application No. PCT/AU99/00949 (Publication No. WO 00/26622) owned by The University of Melbourne, a method and apparatus for producing phase images is disclosed which involves solving the transport of intensity equation to enable both phase and intensity data relating to the object to be determined independently. This enables a phase image of an object to be produced which can provide detail, particularly in biological samples, which is not apparent when a conventional intensity or absorption image of the object is viewed. The contents of the above-mentioned International specification are incorporated into this specification by this reference.

The technique disclosed in the above International application involves taking images of the object. The images include an in focus image and at least one defocused image. Most preferably, at least three images are taken which include an in focus image and two defocused images. One of the defocused images is taken on one side of the in focus image and the other defocused image on the other side of the in focus image. The images are preferably captured by a camera in the form of a

charge coupled device and in order to produce the defocused images and the in focus images, at least one lens of an optical system for producing the images is translated in the direction of the light beam travelling from the object to the camera. The camera is usually located at the focal plane of the optical system. The lens system is translated away from the camera and towards the microscope, in the direction of the light beam until an electrical limit switch is activated. The lens system is then translated in the reverse direction for a pre-calculated distance and a first image is taken to produce a defocused image, the lens system is then translated in the direction of the light beam and a second image is taken by the camera to produce the in focus image at the focal plane, and then the lens system is again translated in the direction of the light beam so as to produce a second defocused image on the other side of the focal plane. The order of taking the in focus and defocused images is not essential and the images can be taken in any order provided it is known which image is the in focus image and which of the two images are the respective defocused images.

The translation of the lens system from one position to another to enable the three images to be taken generally is under the control of a mechanical system which physically moves at least one of the lenses of the optical system. The time taken to translate the lens and to capture the three images sequentially can be significant particularly when biological samples are being analysed. The main reason for this is that the time delay from taking the first image to the third image can involve a significant period in which the nature of the biological sample can change thereby resulting in the object which has produced the first image not being identical to the object which has produced the second or third images because of the change in the biological sample over time.

The time taken to produce the three images of each sample is also significant from the point of view of analysis because it results in data required to produce the phase image taking a significant amount of time to be captured and therefore the number of samples which can be processed and analysed in a given period is relatively small.

Summary of the Invention

The object of this invention is to produce an optical system and method for concurrently producing focused and defocused images and which therefore overcomes the above problem.

The invention, in a first aspect, may be said to reside in an optical system for concurrently producing images of an object, including:

means for splitting a beam of light emanating from the object into at least two paths to thereby produce at least first and second beams of light;

a first beam path having a first length for receiving the first beam of light so the first beam of light travels along the first beam path;

a second beam path having a second length different to the first length for receiving the second beam of light so the second beam of light travels along the second beam path; and

means for imaging the first and second beams at locations separated from one another so that two images are captured concurrently at the two locations.

Thus, according to this aspect of the invention the two images can be concurrently captured thereby ensuring that the images relate to the object in the same physical state, and furthermore, there is no delay between capturing of the images thereby increasing the number of samples which can be analysed in a given time period. The images which are captured can be two defocused images

which are defocused on either side of the focal plane, one defocused image on one side of the focal plane and a focused image, or an in focus image and an image defocused on the other side of the focal plane, if different path lengths are used. If an in focus and a defocused image are captured and used for analysis, this will provide a phase image of the object in a plane between the two images. If the two images used are defocused on either side of the focus image the phase image would be in the focal plane. If an in focus image is not used an approximation of the in focus image can be determined from the two defocused images, one on each side of the focal plane. Alternatively, rather than producing focused and defocused images, images can be produced which have the same focus and which are formed by the first beam of light and the second beam of light having different energies.

Preferably the two separate locations comprise two separate areas of a single charge coupled device so that the at least two images are capture on the same charge coupled device (CCD) array at spaced apart locations on the array one from the other.

Preferably the optical system further includes at least one positive lens and at least one negative lens.

In one embodiment the positive and negative lenses are provided between the object location and the splitting means.

However, in other embodiments the negative lens may be provided between the object location and the splitting means and positive lenses provided in each of the first and second beam paths, or vice versa.

Preferably the first and second beam paths include mirrors for reflecting the first and second light beams along the

first and second beam paths and onto the separate locations of the charge coupled device.

In the preferred embodiment of the invention the optical system includes the first beam path, the second beam path and a third beam path having a length different to the first and second beam paths, and the means for splitting, splits the beam of light emanating from the object into three beams to produce the first, the second and a third beam of light.

Preferably the imaging means images the first beam of light, second beam of light and third beam of light at different locations on the CCD for producing three separate images on the same CCD concurrently with one another.

In this embodiment of the invention the splitting means comprises a plurality of separate beam splitters for splitting the beam into the first beam, the second beam and the third beam.

In a still further embodiment of the invention the optical system includes a fourth beam path, and the means for splitting, splits the beam into the first, the second, the third and a fourth beam of light.

Preferably the imaging means images the fourth beam of light onto a separate location of the charge coupled device so as to produce four separate images concurrently on the charge coupled device.

In one embodiment of the invention the optical system includes beam length adjusting means for adjusting the length of at least one of the said beam paths.

Preferably the adjusting means comprises moving means for

translating the positions of mirrors of the beam path from one place to another to increase the length of the beam path.

Preferably the optical system includes a fixed charge coupled device for receiving the said beams of light at separate locations on the charge coupled device so that a plurality of images are concurrently formed on a single charge coupled device.

Most preferably the detector is a charge coupled device.

The invention may also be said to reside in a method for concurrently producing images of an object, including:

splitting a beam of light emanating from the object into at least two beams to thereby produce at least first and second beams of light;

causing the beams of light to travel along first and second beam paths which have different lengths; and

imaging the beams of light at separate locations from one another so that separate images relating to the first and second beams of light can be captured concurrently.

Preferably the two separate locations comprise two separate areas of a single charge coupled device so that the at least two images are capture on the same charge coupled device array at spaced apart locations on the array one from the other.

In the preferred embodiment of the invention the step of splitting the beam includes splitting the beam of light emanating from the object into three beams to produce the first, the second and a third beam of light and the method further includes causing the beams to travel along three different paths.

Preferably the imaging step images the first beam of light, second beam of light and third beam of light at different locations on the charge coupled device for producing three separate images on the same charge coupled device concurrently with one another.

In this embodiment of the invention the splitting means comprises a plurality of separate beam splitters for splitting the beam into the first beam, the second beam and the third beam.

In a still further embodiment of the step of splitting the beams includes splitting the beam into the first, the second, the third and a fourth beam of light.

Preferably the imaging step images the fourth beam of light onto a separate location of the charge coupled device so as to produce four separate images concurrently on the charge coupled device.

In one embodiment of the invention the method includes the step of adjusting the length of at least one of the said beam paths.

Preferably the adjusting step comprises translating the positions of mirrors of the beam path from one place to another to increase the length of the beam path.

Brief Description of the Drawings

Preferred embodiments of the invention will be described, by way of example, with reference to the accompanying drawings in which:

Figure 1 is a view of an optical system according to the first embodiment of the invention;

Figure 2 shows a modification to the embodiment of Figure 1;

Figure 3 shows a preferred embodiment of the

optical system according to the invention;

Figure 4 shows a still further embodiment of the invention;

Figure 5 is a more detailed view of a charge coupled device for use in the embodiment of Figure 3;

Figure 6 is a view of a charge coupled device for use in the embodiment of Figure 4;

Figure 7 is a view of a further embodiment of the invention; and

Figure 8 is a view of a CCD array used in the embodiment of Figure 7.

Description of the Preferred Embodiments

Figure 1 shows an optical system for concurrently producing three images of an object. A beam of light 10 is transmitted through an object (not shown) in a manner well known. The beam of light is preferably in the visible part of the spectrum. However, the light may also be from other parts of the spectrum. The beam of light 10 which passes through the object carries phase information as well as intensity information relating to the object.

The beam 10 passes through a first lens 12 which is a negative lens and then through a positive lens 14 of generally the same magnitude of power as the lens 12. The beam of light 10 is then received by a beam splitter 16 which is one third reflective and two thirds transmissive so that one third of the beam 10 is reflected as illustrated by beam 18 and two thirds of the light beam 10 pass through the splitter 16 as shown by beam 20. The beam 20 is then received by a second beam splitter 22 which is 50% reflective and 50% transmissive so that half the beam 20 is reflected to produce beam 24 and the other half of the beam 20 continues through the beam splitter as shown by beam 26. The beam 26 impinges on a charge coupled device 30 as will be described in more detail hereinafter.

It will be observed that the beam splitters 16 and 22 split the beam 10 so that the three resultant beams 18, 24 and 26 each contain one third of the original beam 10. It will also be observed that the beam 26 is coaxial with the beam 10 and is effectively a straight line through the lenses 12, 14 and splitters 16 and 22 and therefore will be the shortest path 27 to the charge coupled device 30.

Beam 18 is reflected by a mirror 32 and travels in the direction of beam 18' which is reflected by a further mirror 34 to travel in the direction of beam 18'' and then reflected by a fourth mirror 36 to travel in the direction of beam 18''' and impinge on the charge coupled device 30 at a location on the charge coupled device 30 spaced from the place where the beam 26 impinges. The mirrors 32, 34 and 36 therefore define a path 25, which is of different length to the path 27 traverse by the beam 20 and 26.

The beam 24 is received by a mirror 42 which reflects the beam 24 in the direction of beam 24' and the beam 24' is received by a mirror 44 which reflects the beam 24' in the direction of beam 24''. The beam 24'' is reflected by mirror 46 in the direction of 24''' to impinge on the charge couple device 30 at a location on the device 30 separate from the locations at which the beam 26 and the beam 18''' impinge. The splitter 22, mirror 42, mirror 44 and mirror 46 define a third beam path 29 which is of different length of the two beam paths previously described.

As shown in Figure 5, the charge coupled device 30 receives at three different locations 18a, 26a and 24a images relating to the three beams 18''', 26 and 24''' so as to concurrently produce three separate images on the single charge coupled device 30.

In order to produce the three separate images on the charge coupled device 30, the charge coupled device 30 is effectively divided into three regions 30a, 30b and 30c. The charge coupled device is connected to processing means 50 such as a computer which receives data from the charge coupled device and the processing means is programmed so that it knows which pixels of the charge coupled device 30 are related to which images so that data relating to the three separate images can be separately stored and/or processed by the processor 50. If it is desired to produce the three images 18a, 26a and 24a which have the same perspective as that which would be produced by a single image received by the charge coupled device 30, only part of each region 30a, 30b and 30c is used. Charge coupled devices generally have a ratio of X:Y of 1.5:1 and since the array of pixels of the charge coupled device is divided into the three areas 30a, 30b and 30c the perspective of the three regions will not be X:Y but rather X/3:Y. If it is desired to maintain the same perspective it is therefore necessary to use only part of each of the regions 30a, 30b and 30c of height Y/3.

Three separate images of the object can therefore be captured concurrently with data from the pixels of the charge coupled device 30 being transmitted to the processor 50 to enable the images to be processed to produce the phase image of the object. Thus, the time taken to capture the three images required to produce the phase image is greatly reduced because the images are captured concurrently. Furthermore, the images are captured concurrently and therefore are of the object in the same state.

Preferably the lenses 12 and 14 have the same magnitude of power even though one is a negative lens and the other a positive lens so that no magnification is introduced into the images. The charge coupled device 30 is preferably

located at the focal plane of the image 26a so that the light path 27 defined by the beam 20 and 26 is identical to the focal length of the lenses 12 and 14 (in the other lens in the optical system which may be used to produce the beam 10). This path will be the shortest path because it is effectively a straight line from the splitter 16. The path 25 and the path 29 will be of different length to the path 27 and will produce two defocused images because of that different path length when the beams 18 and 24 impinge on the charge coupled device 30. Because the paths 25 and 29 are necessarily longer than the path 27, the two defocused images 18a and 24a will be on the same side of the focal plane. If it is desired to produce two defocused images, one of which is on one side of the focal plane and the other on the other side of the focal plane, it is necessary to make, for example, the path 25 the in focus path, the path 26 a defocused path on one side of the focal plane (the shorter side) and the other path 29 on the other side of the focal path (ie. the longest path).

In this embodiment of the invention the path lengths 25 and 29 can be adjusted by translating the mirrors 42 and 44, and the mirrors 32 and 34, in the direction of arrow A and B in Figure 1 (or directions opposite those arrows A and B) by mounting the mirrors 42, 44 and 32, 34 on translation stages (not shown).

Thus the path lengths 25 and 29 can be adjusted in length relative to one another and also the path lengths 27 to produce the required focused or defocused images.

Figure 2 shows a modification to the embodiment in Figure 1 in which the positive lens 14 is removed from between the object and beam splitter 16 and a positive lens 14 is located in each of the paths 25, 27 and 29 as shown. Furtherstill, pairs of negative and positive lenses 12 and

14 could be provided in each of the beam paths 25, 27 and 29 rather than providing them between the object and the beam splitter 16.

Figure 3 shows a further embodiment of the invention in which like reference numerals indicate like paths to those previously described.

In this embodiment of the invention the path 27 includes a mirror 50 located after the beam splitter 16 for receiving the beam 10 and reflecting the beam 26 upwardly as shown by reference 26a in Figure 3 out of the plane of the paths 25, 26 and 29 in Figure 1. The beam 26a is reflected by mirror 52 and received by mirror 54 which reflects the beam to mirror 56 which in turn reflects the beam to the same path as the charge coupled device 30 as described with reference to Figure 1 and Figure 5. In this embodiment of the invention the path 27 is made longer because of the inclusion of the mirrors 50, 52, 54 and 56. Thus, one of the paths 25 and 29 can more conveniently be made shorter than the path 27 so that the images 18a, 26a and 24a are a defocused image on one side of the focal plane, the in focus image on the focal plane and a defocused image on the other side of the focal plane respectively.

Once again, the mirrors 32, 34 and mirrors 42, 44 can be mounted on translation stages (not shown) for moving the mirrors in the direction of arrow A to adjust the relative length of the various beam paths 25, 27 and 29. The mounting of the mirrors on a common translation stage enables the mirrors to be moved by the same mechanism and in the same direction so that the path length defined by the mirrors 32 and 34 decreases as the path length defined by the mirrors 42 and 44 increases. Obviously, movement of the mirrors in the same direction opposite to arrow A will cause the path length of the mirrors 32 and 34 to

increase relative to the mirrors 32 and 34. This embodiment also ensures that the difference in path length is an increase or decrease by a constant ratio with respect to one another as the translation stage moves the mirrors 32, 34 and the mirrors 42, 44.

Figure 4 shows a still further embodiment of the invention in which four concurrent images are produced. Like reference numerals indicate like paths to those described with reference to Figure 3.

In this embodiment splitter 16 is 25% reflective and 75% transmissive and the 25% of the beam which is reflected by the splitter 16 traverses a fourth path 35 which is defined by a mirror 71, mirror 72 and mirror 73. The path 35 is in the same vertical plane as the path 27 described with reference to Figure 3.

The light which passes through the splitter 16 is received by splitter 22 which is 33% reflective and 66% transmissive and the light which is reflected travels along path 27 which is the same as the path 27 described in the embodiment of Figure 3. Of the 66% of the light which is transmitted by the splitter 22, 50% of that light is reflected by a further beam splitter 23 to traverse path 25 previously described and the remaining light transmits through the splitter 23 and traverses path 29 by being reflected to mirror 42 by mirror 31.

Thus, four separate images are concurrently and separately produced on the charge coupled device 30.

The charge coupled device 30 according to this embodiment is shown in Figure 6 and the charge coupled device 30 is divided into four equally size segments, each of which will have the same perspective as the original charge coupled device 30 because the sides X and Y are

effectively divided in half to produce the four segments. Thus, the four images are imaged on the charge coupled device 30 at four separate locations on the charge coupled device 30 with the image 35a being the image produced by the path 35 in Figure 4. This embodiment has the advantage that the entire charge coupled device 30 is utilised in order to produce the four images rather than only part of the charge coupled device as in the embodiment of Figure 5 if it is desired to maintain the same perspective as the original charge coupled device 30.

Once again, in the embodiment of Figure 4, the mirrors 42, 44 and 32, 34 may be mounted on translation stages (not shown) so that the path lengths 25 and 29 can be adjusted in length by moving the mirrors in the direction of arrow A and B. Similarly, the mirrors 71 and 72 can also be mounted on translation stages for moving the mirrors in the direction of arrow C (which is perpendicular to the direction of movement shown by arrow A and B) to adjust the length of the path 35 if desired.
The addition of a fourth image in the embodiment of Figure 4 will add to the precision of the phase retrieval algorithm according to the above-mentioned International application because it will provide more data for enabling a more accurate solution to the transport of intensity equation.

Figures 7 and 8 show a still further embodiment of the invention. This embodiment is similar to the embodiment of Figure 3, except that the charge coupled device 30 shown in Figure 8 is a square which is turned 45° so that it is oriented as shown in Figure 8. The mirror 56 is shifted from the position shown in Figure 3 so that it is above the plane in which the mirrors 34 and 44 are contained. Furthermore, masks (not shown) can be used to confine the image which is transmitted along the paths 25, 27 and 29 to a diamond shape so that the three images are

concurrently imaged on to the charge coupled device 30 in the position shown in Figure 8. This embodiment allows a square CCD 30 to be used, which are more easily and more commonly available, and for the three images to be imaged onto the square CCD array 30 by orienting the CCD array 30 so that it is a diamond shape, as shown in Figure 8, and imaging three diamond shaped images onto the charge coupled device, as is shown in Figures 7 and 8.

The masks referred to above can be located anywhere in the paths 25, 27 and 29 prior to the CCD device 30 simply for confining the image which is received by the CCD 30 to the diamond configuration as shown in Figure 8, to separate the images and to maximise the amount of pixels which are used in the CCD device for receiving the three concurrent images from the paths 25, 27 and 29.

Since modifications within the spirit and scope of the invention may readily be effected by persons skilled within the art, it is to be understood that this invention is not limited to the particular embodiment described by way of example hereinabove.

Claims

1. An optical system for concurrently producing images of an object, including:

means for splitting a beam of light emanating from the object into at least two paths to thereby produce at least first and second beams of light;

a first beam path having a first length for receiving the first beam of light so the first beam of light travels along the first beam path;

a second beam path having a second length different to the first length for receiving the second beam of light so the second beam of light travels along the second beam path; and

means for imaging the first and second beams at locations separated from one another so that two images are captured concurrently at the two locations.

2. The system of claim 1 wherein the two separate locations comprise two separate areas of a single charge coupled device so that the at least two images are capture on the same charge coupled device (CCD) array at spaced apart locations on the array one from the other.

3. The system of claim 1 wherein the optical system further includes at least one positive lens and at least one negative lens.

4. The system of claim 3 wherein the positive and negative lenses are provided between the object location and the splitting means.

5. The system of claim 1 wherein the first and second beam paths include mirrors for reflecting the first and second light beams along the first and second beam paths and onto the separate locations of the charge coupled device.

6. The system of claim 1 wherein the optical system includes the first beam path, the second beam path and a third beam path having a length different to the first and second beam paths, and the means for splitting, splits the beam of light emanating from the object into three beams to produce the first, the second and a third beam of light.

7. The system of claim 6 wherein the imaging means images the first beam of light, second beam of light and third beam of light at different locations on the CCD for producing three separate images on the same CCD concurrently with one another.

8. The system of claim 7 wherein the splitting means comprises a plurality of separate beam splitters for splitting the beam into the first beam, the second beam and the third beam.

9. The system of claim 6 wherein the optical system includes a fourth beam path, and the means for splitting, splits the beam into the first, the second, the third and a fourth beam of light.

10. The system of claim 9 wherein the imaging means images the fourth beam of light onto a separate location of the charge coupled device so as to produce four separate images concurrently on the charge coupled device.

11. The system of claim 1 wherein the optical system includes beam length adjusting means for adjusting the length of at least one of the said beam paths.

12. The system of claim 11 wherein the adjusting means comprises moving means for translating the positions of mirrors of the beam path from one place to another to

increase the length of the beam path.

13. The system of claim 1 wherein the optical system includes a fixed charge coupled device for receiving the said beams of light at separate locations on the charge coupled device so that a plurality of images are concurrently formed on a single charge coupled device.

14. The system of claim 6 wherein the charge coupled device is a substantially square charge coupled device, and wherein one of the paths causes light to impinge on the charge coupled device in a different plane to the other of the paths so that the images locate on the charge coupled device adjacent corners of the substantially square charge coupled device.

15. The system of claim 14 wherein the charge coupled device is oriented such that the charge coupled device forms a diamond shape relative to a plane containing at least two of the paths.

16. A method for concurrently producing images of an object, including:

splitting a beam of light emanating from the object into at least two beams to thereby produce at least first and second beams of light;

causing the beams of light to travel along first and second beam paths which have different lengths; and

imaging the beams of light at separate locations from one another so that separate images relating to the first and second beams of light can be captured concurrently.

17. The method of claim 16 wherein the two separate locations comprise two separate areas of a single charge coupled device so that the at least two images are capture on the same charge coupled device array at spaced apart

locations on the array one from the other.

18. The method of claim 16 wherein the step of splitting the beam includes splitting the beam of light emanating from the object into three beams to produce the first, the second and a third beam of light and the method further includes causing the beams to travel along three different paths.

19. The method of claim 18 wherein the imaging step images the first beam of light, second beam of light and third beam of light at different locations on the charge coupled device for producing three separate images on the same charge coupled device concurrently with one another.

20. The method of claim 19 wherein the splitting means comprises a plurality of separate beam splitters for splitting the beam into the first beam, the second beam and the third beam.

21. The method of claim 16 wherein the step of splitting the beams includes splitting the beam into the first, the second, the third and a fourth beam of light.

22. The method of claim 21 wherein the imaging step images the fourth beam of light onto a separate location of the charge coupled device so as to produce four separate images concurrently on the charge coupled device.

23. The method of claim 16 wherein the method includes the step of adjusting the length of at least one of the said beam paths.

24. The method of claim 23 wherein the adjusting step comprises translating the positions of mirrors of the beam path from one place to another to increase the length of the beam path.

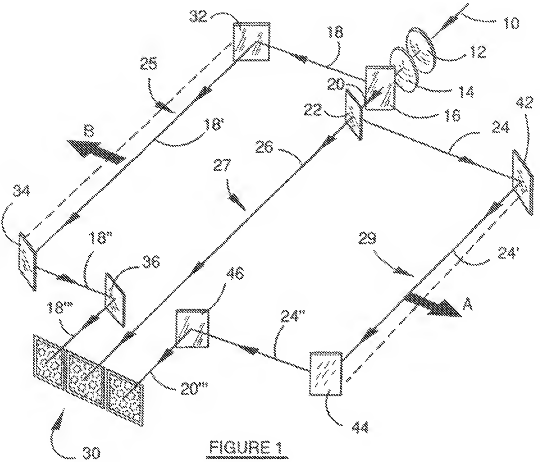

FIGURE 1

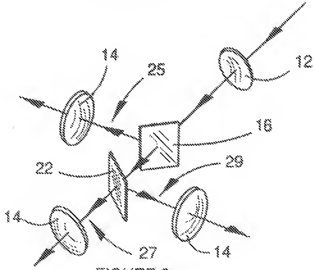

FIGURE 2

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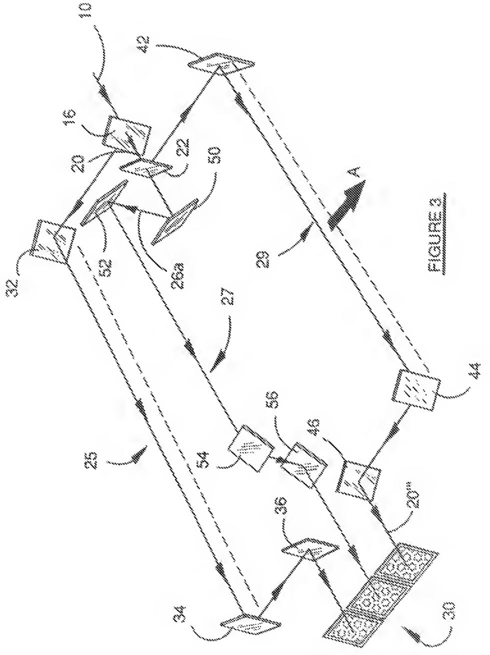

FIGURE 3

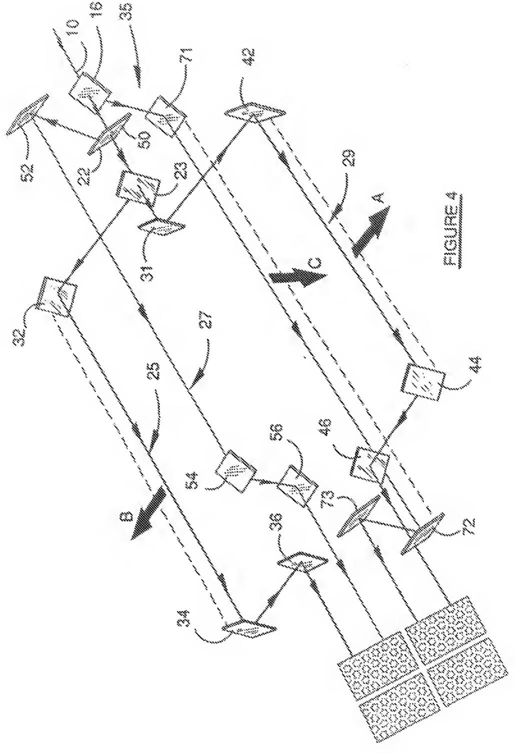

FIGURE 4

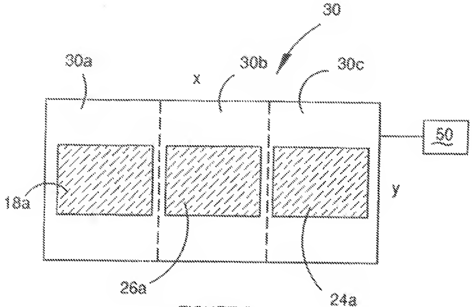

FIGURE 5

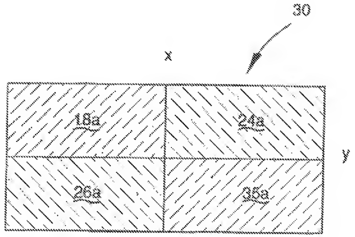

FIGURE 6

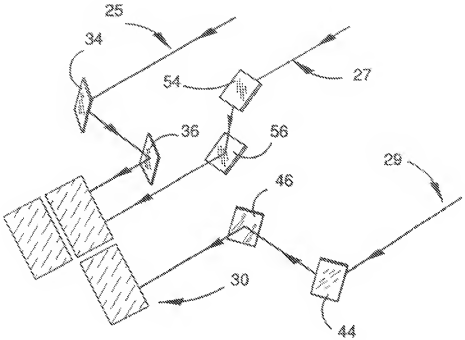

FIGURE 7

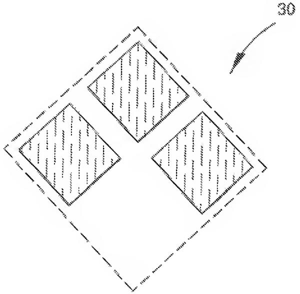

FIGURE 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU02/00967

A.	CLASSIFICATION OF SUBJECT MATTER
Int. Cl. 7	G02B 27/10, 27/50, 21/18, G01J 9/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
DWPI, JAPIO IPC G02B, G01J 9/- with Keywords: beamsplit; split, divid, beam; path length, delay; imag; unfocus, defocus, out of focus

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4360885 A (EDGAR) 23 November 1982 Columns 7-8, Figures 3, 4, 7	1-24
X	US 4467188 A (SUZUKI et al.) 21 August 1984 Columns 1-3, Figures 1-3	1-7, 9-10, 13, 16-19, 21-22
X	US 4398788 A (DIETZ) 16 August 1983 Column 2, Figure 1	1, 3, 11, 16, 23

[X] Further documents are listed in the continuation of Box C [X] See patent family annex

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
6 September 2002	16 SEP 2002

Name and mailing address of the ISA/AU	Authorized officer
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU02/00967

C (Continuation). **DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4647154 A (BIRNBACH et al.) 3 March 1987 Columns 4-5, Figure 1	1, 3-4, 11-12, 16, 23-24
X	US 4626674 A (OINOUE) 2 December 1986 Columns 6-8, Figure 6	1, 16
X	US 6023057 A (GAFFARD et al.) 8 February 2000 Columns 3-5, Figures 1-2	1-4, 11-13, 16-17, 23-24

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/AU02/00967

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
US	4360885	NONE					
US	4467188	DE	3200137	GB	2092854	JP	57114112
US	4398788	DE	2948687	FR	2471615	GB	2065325
		JP	56102820	NL	8006545	SE	8008406
US	4647154	AU	31162/84	CA	1264580	EP	133356
		ES	534651	ES	8506907	IN	161886
		JP	60057317				
US	4626674	JP	60108816	JP	59146010	JP	59146009
US	6023057	EP	840158	FR	2755235	JP	10142067

END OF ANNEX